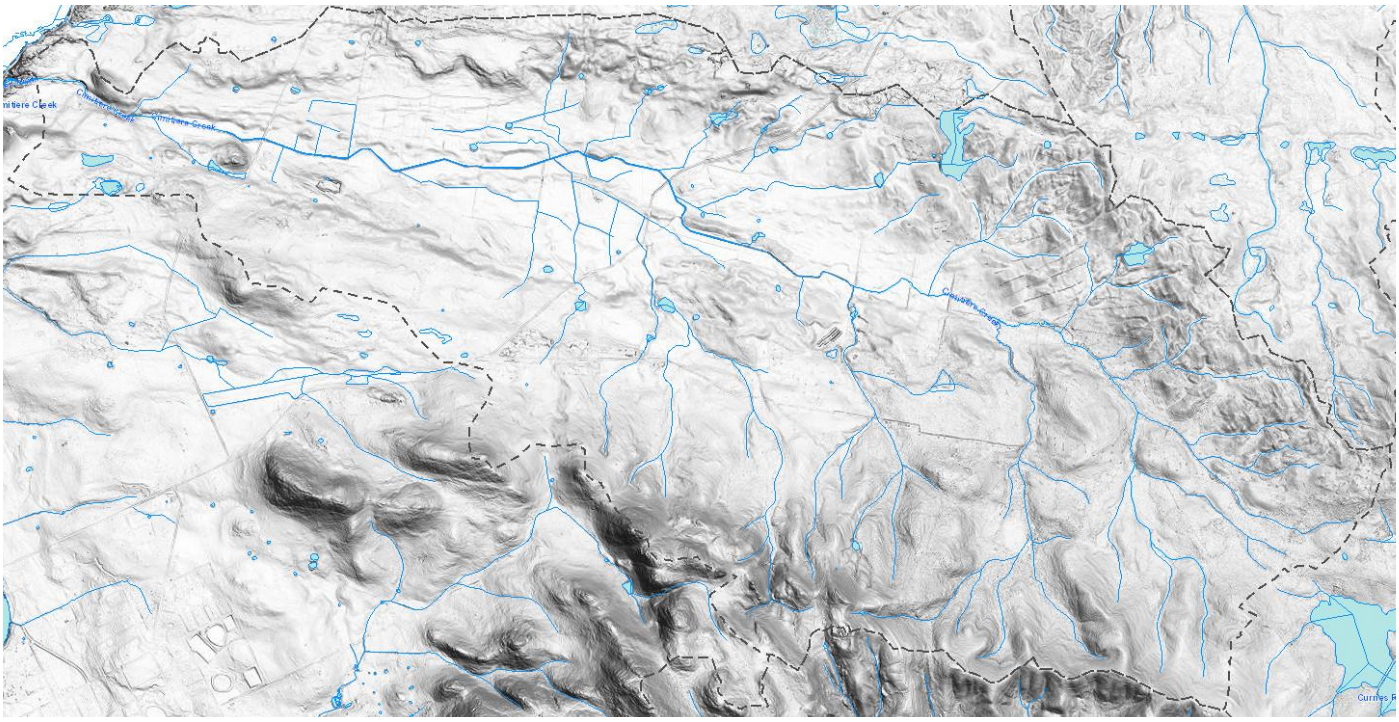
Appendix L
Flood Study

Cimitiere Plains Solar Farm

ENVOCA ENVIRONMENTAL CONSULTANCY

SOLAR FARM FLOOD STUDY - CIMITIERE CREEK TASMANIA

REPORT – FOR ISSUE



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101 West Fyans Street
Newtown, VIC, 3220

Tel: (03) 4201 0388
Fax: (02) 9262 6208
Email: wma@wmawater.com.au
Web: www.wmawater.com.au

SOLAR FARM FLOOD STUDY - CIMITIERE CREEK TASMANIA

REPORT – FOR ISSUE

FEBRUARY 2022

Project Solar Farm Flood Study - Cimitiere Creek Tasmania	**Project Number** 121089
Client Envoca Environmental Consultancy	**Client's Representative** Daryl Brown
Project Manager Mark Colegate	

Revision History

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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ARF	Areal Reduction Factor
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
CL	Continuous Loss
DEM	Digital Elevation Model
EIA	Effective Impervious Area
ELVIS	ELeVation Information System (data sharing platform)
GPU	Graphics Processing Unit
HPC	Heavily Parallelised Compute
ICA	Indirectly Connected Area
IFD	Intensity, Frequency and Duration (Rainfall)
IL	Initial Loss
LiDAR	airborne Light Detection And Ranging
m AHD	meters above Australian Height Datum
PMF	Probable Maximum Flood
RFFE	Regional Flood Frequency Estimation
RPA	Rural Pervious Area
TauDEM	Terrain analysis using Digital Elevation Models
TUFLOW	Two-dimensional Unsteady FLOW (hydraulic model)
WBNM	Watershed Bounded Network Model (hydrologic model)

ADOPTED TERMINOLOGY

Australian Rainfall and Runoff (ARR, ed Ball et al, 2019) recommends terminology that is not misleading to the public and stakeholders. Therefore, the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example, there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

ARR 2019 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are subtly different.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality. Therefore, the term Exceedances per Year (EY) is recommended. Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example, an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6-month Average Recurrence Interval where there is no seasonality, or an event that is likely to occur twice in one year.

The Probable Maximum Flood is the largest flood that could possibly occur on a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding a PMP does not translate to a PMF of the same AEP. Therefore, an AEP is not assigned to the PMF.

This report has adopted the approach recommended by ARR and uses % AEP for all events rarer than the 50 % AEP and EY for all events more frequent than this.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	19.5
	0.02	2	50	49.5
	0.01	1	100	99.5
Very Rare	0.005	0.5	200	199.5
	0.002	0.2	500	499.5
	0.001	0.1	1000	999.5
	0.0005	0.05	2000	1999.5
Extreme	0.0002	0.02	5000	4999.5
			↓	
			PMP/ PMP Flood	

1. INTRODUCTION

WMAwater was engaged by Envoca Environmental Consultancy to prepare a Flood Study to define the characteristics of flooding affecting the proposed site of a solar farm ('the site'), approximately 5km North-East of George Town, in northern Tasmania.

1.1. Study Area

The location of the proposed solar farm was provided within a study area of interest of just over 8 km² (Figure 1). The site represents is predominantly cleared agricultural land. The southeast corner of the site is densely forested and there are dense stands of trees (windbreaks) throughout. The majority of the upper Cimitiere Creek catchment is also densely forested. The site is dissected by Soldiers Settlement Road and Cimitiere Creek.

Cimitiere Creek rises below Mount George at an elevation of 112 m AHD and flows north into the Tasman Sea. Cimitiere Creek falls approximately 104 metres over its 11.7 km length. The catchment area upstream of Old Aerodrome Road, i.e., the study catchment for this report, is approximately 27 km² (Figure 1).

1.2. Scope

The main objective of this study is to define the flood behaviour of the Cimitiere Creek waterway and provide flood information for the solar farm site. The scope of this study includes:

- development of hydrologic and hydraulic models for the Cimitiere Creek Catchment upstream of Old Aerodrome Road, covering the whole solar farm site
- existing conditions flood modelling and mapping for 1% AEP flood event
- provision of GIS layers of flood behaviours and flood study report

2. METHODOLOGY

A hydrologic-hydraulic flood model was developed to address the complex runoff generation and routing processes in the catchment and used to quantify flood characteristics of the catchment under existing conditions. Key aspects of the flood behaviour to be resolved by the modelling approach are:

- **Hydrology –** converting design rainfalls to runoff in a manner consistent with the 2019 revision of Australian Rainfall and Runoff (ARR 2019, Reference 1)
- **Hydraulics –** resolve the flow behaviour of runoff throughout the study area including:
    - "Mainstream" flooding in the main drainage lines
    - Overland flow through the rest of the catchment

The study catchment was delineated into sub-catchments based on LiDAR Digital Elevation Model (DEM). A semi-distributed network hydrologic model, i.e., Watershed Bounded Network Model (WBNM, Reference 2), was established for the entire catchment to simulate the sub-catchment runoff generation and concentration processes and channel routing process. Hydrographs from sub-catchments were extracted from the hydrologic model and used as inflows to a 2D hydraulic model, i.e., Two-dimensional Unsteady FLOW (TUFLOW, Reference 3), which characterise the flow propagation throughout the major flow paths within the catchment. The hydrologic-hydraulic flood model schematics is shown in Figure 2.

2.1. Digital Elevation Model

Four (4) LiDAR-derived DEM datasets were obtained from ELVIS, i.e., the Elevation and Depth Foundation Spatial Data Portal (Reference 4). The basic information of the datasets is summarised in Table 1.

Table 1: LiDAR-derived Digital Elevation Model

Dataset	Program	Commissioned by	Acquisition Date	Grid Size	Accuracy
Tamar2008	Climate Futures	ACECRC	Mar 2008	1 metre	0.25 m (H), 0.25 m (V)
NorthEast2010	Forestry Tasmania	Forestry Tasmania	Jan – Apr 2010	1 metre	0.15 m (H), 0.15 m (V), 68% CI
BurnieDevonportLaunceston2013	Tas Coastal	Geoscience Australia	Mar – Apr 2014	1 metre	0.30 m (H), 0.80 m (V), 95% CI
Beechford2019	Flood Recovery	DPIPWE	Mar 2019	1 metre	0.50 m (H) 0.30 m (V), 95% CI

A catchment-wide DEM (Figure 3) was established through the integration of the above LiDAR DEM datasets, with priority given to newer dataset.

2.2. Hydrology

2.2.1. Sub-catchment Delineation

The entire catchment was delineated into 35 sub-catchments, as shown in Figure 2. The delineation was carried out through two steps:

- automatic sub-catchment delineation by applying a mathematical algorithm called Terrain analysis using Digital Elevation Models (TauDEM, Reference 5) to LiDAR DEM; and
- manual refinement of sub-catchment delineation based on the review of cadastre, the latest aerial imageries, and the site boundary.

2.2.2. Design Rainfall

The design rainfall intensity-frequency-duration (IFD) data was obtained from Bureau of Meteorology (BOM)'s Design Rainfall Data System (2016). The IFD was adjusted by the Areal Reduction Factor (ARF) from ARR Data Hub based on the catchment size and was then applied to the burst temporal patterns obtained from ARR Data Hub (Reference 6), to create burst storm events. The median preburst was then superimposed to the burst to create full storm events as hydrologic model input data.

2.2.3. Losses

In WBNM, the storm initial and continues losses (IL & CL) are defined for three different surface types within each sub-catchment. The three types of surfaces are Rural Pervious Area (RPA), Indirectly Connected Area (ICA), and Effective Impervious Area (EIA).

The Cimitiere Creek Catchment is a rural catchment, predominantly covered by RPA with a minor proportion of ICA and no EIA. For this study, the ICA was set to be 3% - 5% of different sub-catchments based on visual inspection of the aerial imagery of each sub-catchment. The rest of the area for each sub-catchment, i.e., 95% - 97%, was deemed to be RPA.

The storm IL and CL for RPA obtained from ARR Data Hub (catchment average) were used as initial values, which were then refined during the calibration process (Section 2.2.5). The IL and CL for ICA were set in relation to those for RPA. The initial value and suggested range of IL and CL are summarised in Table 2.

Table 2: Initial Value and Suggested Range of Losses

Surface Type	IL (mm)	CL (mm)
Rural Pervious Area	15 – 30 (24.9 from ARR Datahub)	2 – 5 (4.4 from ARR Datahub)
Indirectly Connected Area	$0.7 \times IL_{RPA}$	$0.6 \times CL_{RPA}$

2.2.4. Routing Parameters

WBNM simulates the sub-catchment routing (runoff concentration) and channel routing (streamflow propagation) through simple conceptualised methods. It requires a sub-catchment lag parameter and a stream lag factor to be defined which describes the average travel time within and between sub-catchments. These parameters can be catchment specific, associated with roughness, slope, and shape of catchments, and are typically optimised through calibration.

The suggested range for the sub-catchment and stream routing parameters were summarised in Table 3, which were used for calibration as detailed in Section 2.2.5.

Table 3: Suggested Range of Routing Parameters

Routing Parameters	Value
Sub-catchment Lag (C)	1.3 – 2.0
Stream Lag Factor (R)	0.8 – 1.5

2.2.5. Calibration

Calibration to recorded events can be conducted to reduce the uncertainty of those parameters, however, the lack of streamflow gauges within the Cimitiere Creek catchment does not allow this. Therefore, the Regional Flood Frequency Estimation (RFFE) tool provided by ARR 2019 was employed to provide a reference of the peak discharge to calibrate the loss and routing parameters.

The semi-distributed model (35 sub-catchments) was temporarily set to purely rural (i.e., 100% RPA) to be comparable with RFFE. A lumped model of the entire catchment, also purely rural, was used as an intermediate model, which does not have the stream lag parameter (R), to reduce the dimension of parameter space and mitigate the underdetermination issue in the calibration process. The calibrated routing parameters are summarised in Table 4. The peak discharges for different AEPs are illustrated in Diagram 1.

Table 4: Calibrated WBNM Parameters

WBNM Parameters	Value
IL_{RPA}	20.0
CL_{RPA}	4.0
Sub-catchment Lag (C)	2.0
Stream Lag Factor (R)	1.35

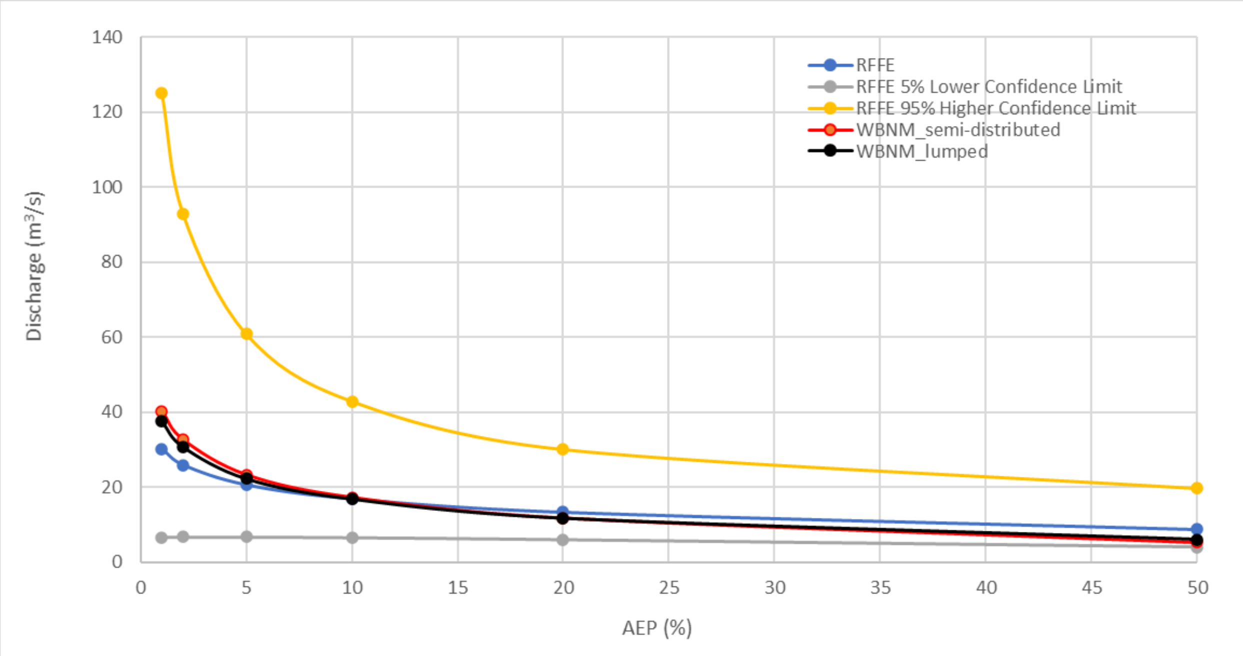

Diagram 1: Estimated Peak Discharges - WBNM vs RFFE

It is shown that there is a good consistency between semi-distributed and lumped model, indicating that the calibrated sub-catchment lag (C) and stream lag factor (R) have similar efficacy representing the routing delays within the catchment. The modelled peak flows are very close to RFFE for 10% AEP. It is generally considered that the RFFE is more reliable for 10% AEP design events than for rarer events, such as 1% AEP, due to the larger size of sample population.

The modelled peak flows are slightly higher than RFFE for rarer AEPs (e.g., 1% to 5%) and slightly lower than RFFE for more frequent AEPs (e.g., 20% and 50%), which however are all within the 90% Confidence Interval. The slight overestimation in 1% AEP indicates that the calibrated model might be a little conservative in terms of estimation of 1% AEP flooding characteristics.

It should be noted that RFFE techniques are subject to uncertainty, which however was the best available information to use at the time of modelling. The accuracy in this calibration should be considered relative to the data available.

The calibrated parameters in Table 4 were adopted for the final 1% AEP design event modelling under existing condition, i.e., 95% - 97% RPA as discussed in Section 2.2.3.

2.2.6. Critical Duration and Temporal Pattern Selection

The calibrated hydrologic model was adopted for 1% AEP design event modelling under existing conditions. The hydrologic modelling was conducted for ten (10) temporal patterns of each duration from 10 min to 48 hr. The critical duration was identified to be 6 hr based on the flow predictions from WBNM at sub-catchment C34, i.e., downstream boundary of the site. The temporal pattern (TP-6559) producing the lowest flow above mean flow was selected as a representative temporal pattern, which was then proceeded to hydraulic modelling. The boxplot of the flow predictions at C34 is shown in Diagram 2.

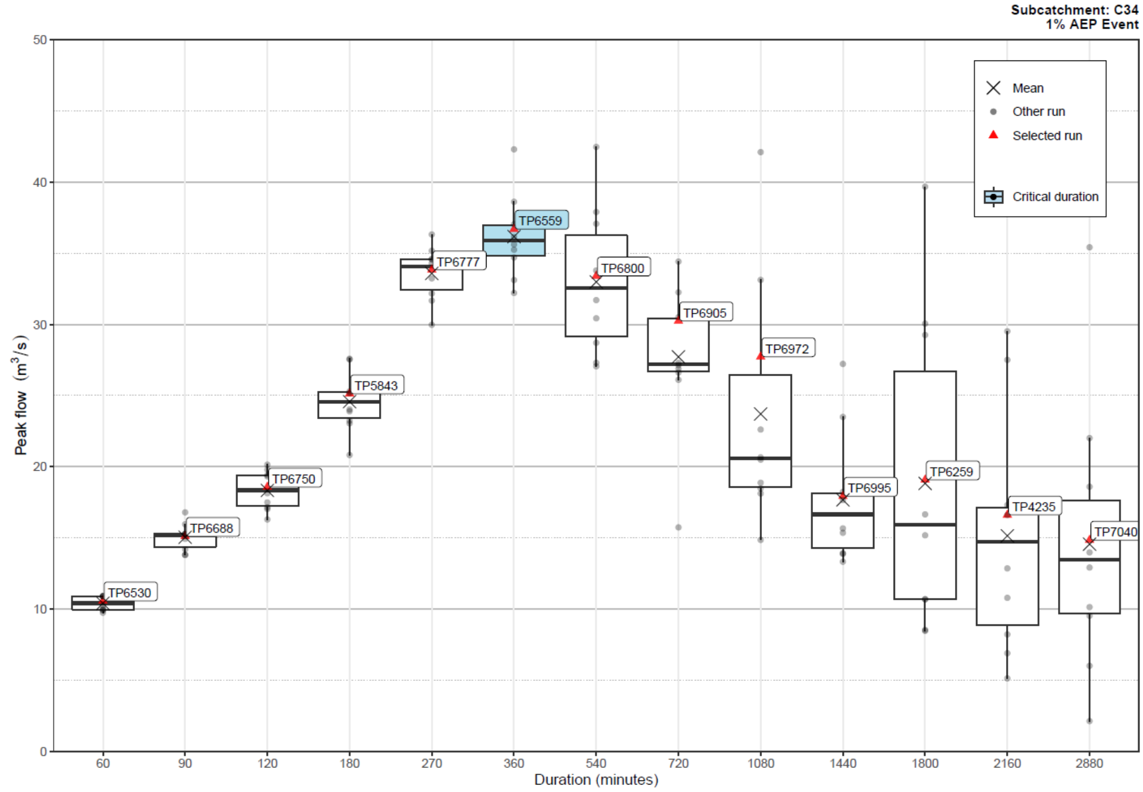

Diagram 2: Boxplot of the flow predictions at C34 from the WBNM.

2.3. Hydraulics

2.3.1. Model Setup

Hydraulic modelling was undertaken using TUFLOW HPC (build 2020-10-AA-iSP-w64) with Graphics Processing Unit (GPU) solver (Reference 3), a widely utilised 1D and 2D flood simulation software. The key features of the hydraulic model are summarised below:

- The hydraulic model extent covers the entire stream and overland flow network from the sink (discharge location) of the most upstream sub-catchment (C01) to the immediate downstream of Old Aerodrome Road, as depicted in Figure 2.
- Grid size of 2 metre was adopted.
- The LiDAR-based DEM model was used as base topography.
- Some sections of Cimitiere Creek, where LiDAR-based DEM exhibits triangulation issues and does not correctly represent the continuous conveyance feature of the waterway, were treated by superimposing break lines along the riverbed.
- The hydrographs of all sub-catchments were extracted from WBNM and used as inflows to the hydraulic model at the inflow locations, i.e., SA polygons, (Figure 4)
- The downstream boundary condition was placed far enough from the site boundary, i.e., downstream of Old Aerodrome Road, to minimise its impact on the modelled flood characteristics in the site (Figure 4).
- The surface roughness (Manning's *n*) was schematised into forest, pasture, and main road in accordance the aerial imagery, as depicted in Figure 5. The Manning's *n* values are summarised in Table 5.
- There are several culverts in the modelling extent which are critical hydraulic constraints. Due to the lack of information, the dimensions of the culverts were roughly estimated

based on inspection of LiDAR DEM (i.e., channel profiles) and aerial imagery. The invert levels were set according to the upstream and downstream surface levels interpreted from the LiDAR DEM. The locations of those culverts are shown in Figure 6.

Table 5: Manning's 'n' Coefficient

ID	Land Use	Manning's '*n*'
1	Forest	0.08
2	Pasture	0.04
3	Main Road	0.02

2.3.2. Flood Mapping

Hydraulic modelling was conducted for the selected duration (6 hr) and temporal pattern (TP-6559) of 1% AEP. The flood characteristics was illustrated through mapping of flood depth, level, velocity, hydraulic hazard, and hydraulic categorisation.

2.3.2.1. Hydraulic Hazard

Hazard classification plays an important role in informing floodplain risk management in an area. Provisional hazard categories have been determined for the study catchment in accordance with the Australian Disaster Resilience Handbook Collection (Reference 7). A summary of this categorisation is provided in Diagram 3.

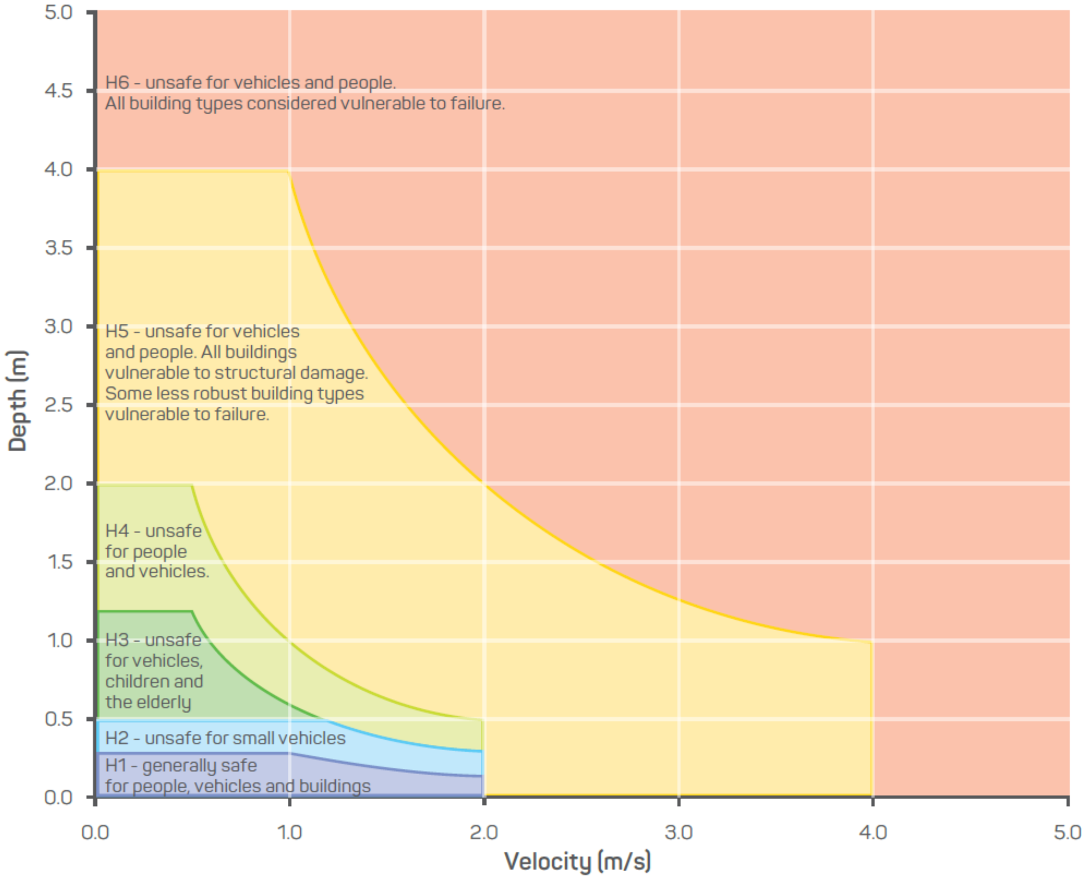

Diagram 3: General Flood Hazard Vulnerability Curves (ADR)

This classification provides a more detailed distinction and practical application of hazard categories, identifying the following 6 classes of hazard:

- H1 – No constraints, generally safe for vehicles, people and buildings;
- H2 – Unsafe for small vehicles;
- H3 – Unsafe for all vehicles, children and the elderly;
- H4 – Unsafe for all people and all vehicles;
- H5 – Unsafe for all people and all vehicles. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure. Buildings require special engineering design and construction; and
- H6 – Unsafe for all people and all vehicles. All building types considered vulnerable to failure.

2.3.2.2. Hydraulic Categorisation

Floodplains can be classified into the following hydraulic categories depending on the flood function:

- Floodways
- Flood Storage and
- Flood Fringe.

There is no quantitative definition of these three categories or accepted approach to differentiate between the various classifications. The delineation of these areas is somewhat subjective based on knowledge of an area and flood behaviour, hydraulic modelling, and previous experience in categorising flood function. A few approaches are available, such as the method defined by Howells *et al* (Reference 8).

For this study, hydraulic categories were defined by the following criteria, which has been tested and is considered to be a reasonable representation of the flood function of this catchment.

- Floodway is defined as areas where:
  - the peak value of velocity multiplied by depth (V x D) > 0.25 m^2/s, **AND** peak velocity > 0.25 m/s, **OR**
  - peak velocity > 1.0 m/s **AND** peak depth > 0.1 m.

The remainder of the floodplain is either Flood Storage or Flood Fringe:

- Flood Storage comprises areas outside the floodway where peak depth > 0.5 m, and
- Flood Fringe comprises areas outside the Floodway where peak depth ≤ 0.5 m.

3. RESULTS

The 1% AEP flood characteristics are illustrated through below maps:

- Peak Flood Depth and Level Contours (Figure B1)
- Peak Flood Velocity (Figure B2)
- Hydraulic Hazard (Figure B3)
- Hydraulic Categorisation (Figure B4)

All the maps are presented for flood water depth ≥ 50 mm. Areas with water depth below 50 mm are treated as non-inundated area. The maps were schematised for visualisation purpose. The original raster layers (ASCII) with modelled full flood extent are also provided, which should be used in preference to the figures in this report as they provide more detail.

3.1. Summary of Results

The proposed solar farm site covers the middle section of Cimitiere Creek, i.e., approximately 5.6 km. The Creek enters the eastern boundary of the site, carrying 21.3 m^3/s of peak flow during 1% AEP event. As the flow propagates westward through the site, the Creek receives inflows from tributaries from north and south sub-catchments. The peak inflows entering the north and south boundaries of the site are 3.9 m^3/s and 12.1 m^3/s, respectively, during 1% AEP event. The total peak outflow across the western (downstream) boundary of the site is 53.4 m^3/s, with considerable runoff contribution from the site.

The flood level grades from 51.5 m AHD to 16.5 m AHD across the site. The eastern half of the site (upstream part) has a relatively lower flood risk in general, with majority of the Floodway and Flood Storage area (Figure B4) contained within the natural channel. The western half of the site (downstream part) has a relatively higher flood risk, with significant flood water propagation within the riparian zone (Floodway in Figure B4) resulting in hazard categories of H3 and H4 (Figure B3). Nevertheless, the majority of the site is outside the inundated area, which are safe for solar farm development.

3.2. Flood Hotspots

There are several areas within the catchment which experience a higher flood risk during a 1% AEP event. These flooding hotspots should be paid more attention during design and development. The flood hotspots are summarised below.

- Dams and basins and their immediate downstream areas. There are several dams/basins in the site, along the tributaries to Cimitiere Creek, as highlighted in Diagram 4. The water is reasonably deep (0.8 m – 1.5 m) in those dams/basins during 1% AEP flooding. The area immediate downstream of those dams/basins are subject to flood risk if the dam wall failed during flooding.
- Soldiers Settlement Road across Cimitiere Creek. The road embankment is shown to cause flood water attenuation upstream of the road, as highlighted in Diagram 5. The flood depth is up to 0.65 m and the flood extent of depth above 0.3 m is approximately 200 m wide. This is however subject to uncertainty associated with the assumption made for the

culvert below Soldiers Settlement Road, which can be improved through on-site measurement or survey.

- The riparian zone along the Creek downstream of the confluence of the Cimitiere Creek and the southern tributary, as highlighted in Diagram 6, is subject to inundation during 1% AEP event. The flood depth is up to 1.75 m in channel and 0.8 m in riparian zone. The width of the inundated area varies from 80 m to 200 m. Significant proportion of the inundated area in the riparian zone is classified as Floodway or Flood Storage (Figure B4) and hazard categories of H3 – unsafe for all vehicles, children and the elderly or H4 – unsafe for all people and all vehicles (Figure B3).

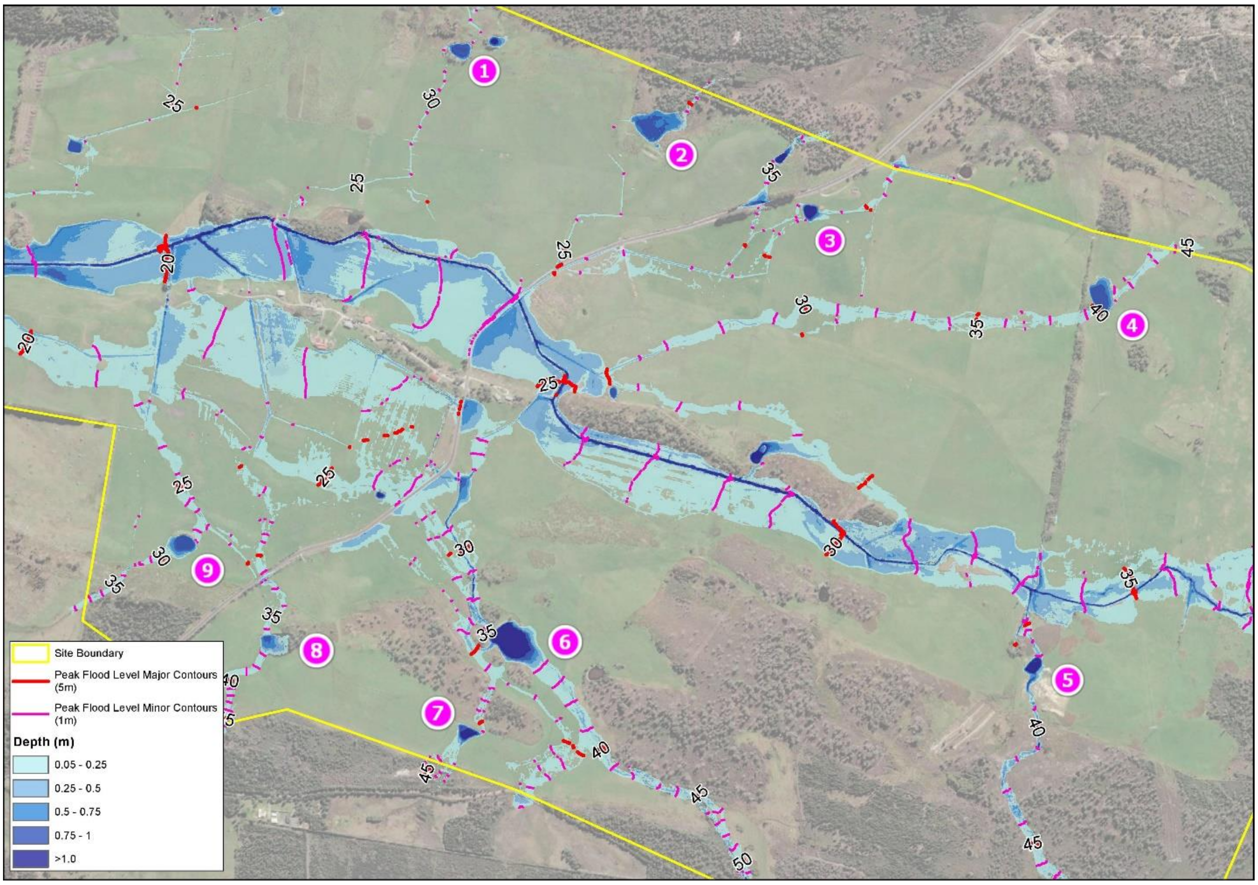

Diagram 4: Dams and Basins

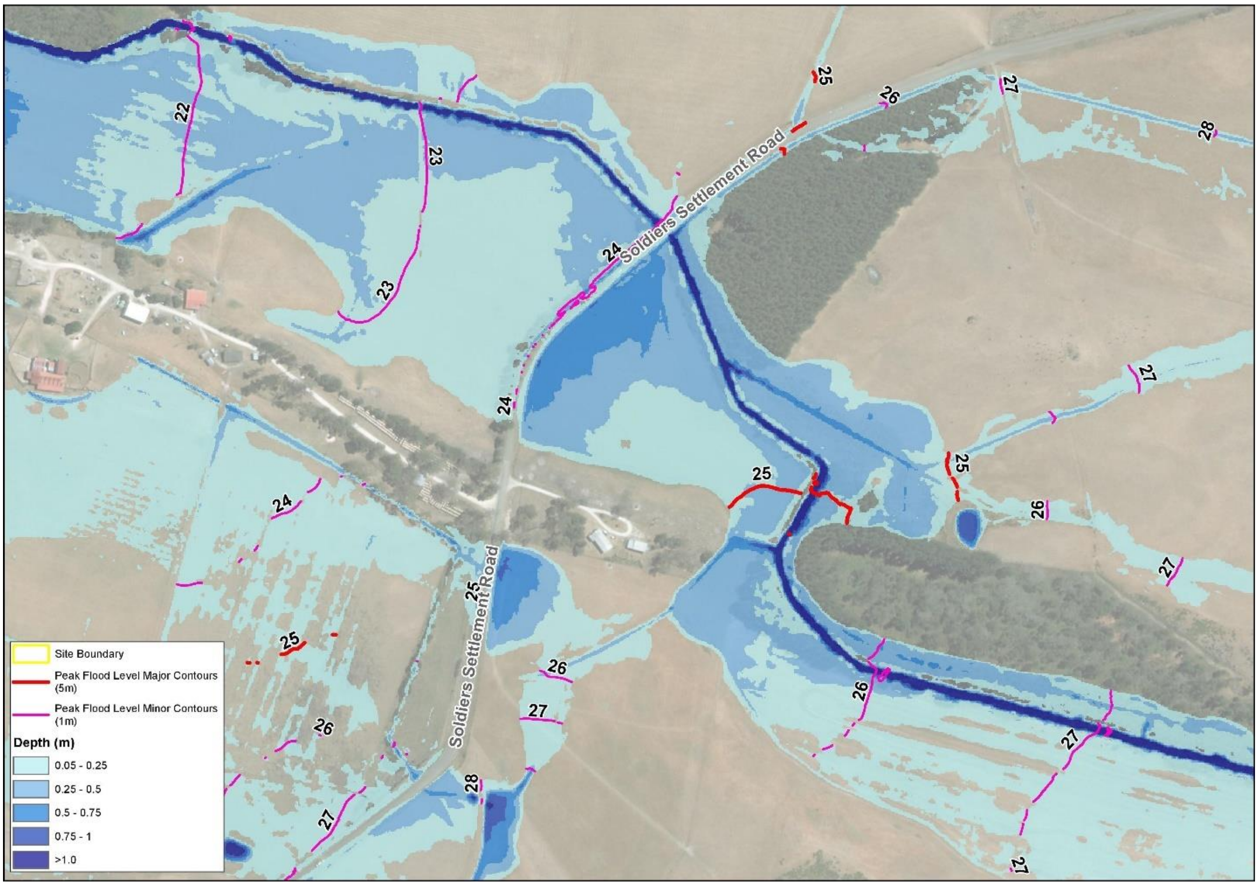

Diagram 5: Flood Attenuation Upstream of Soldiers Settlement Road

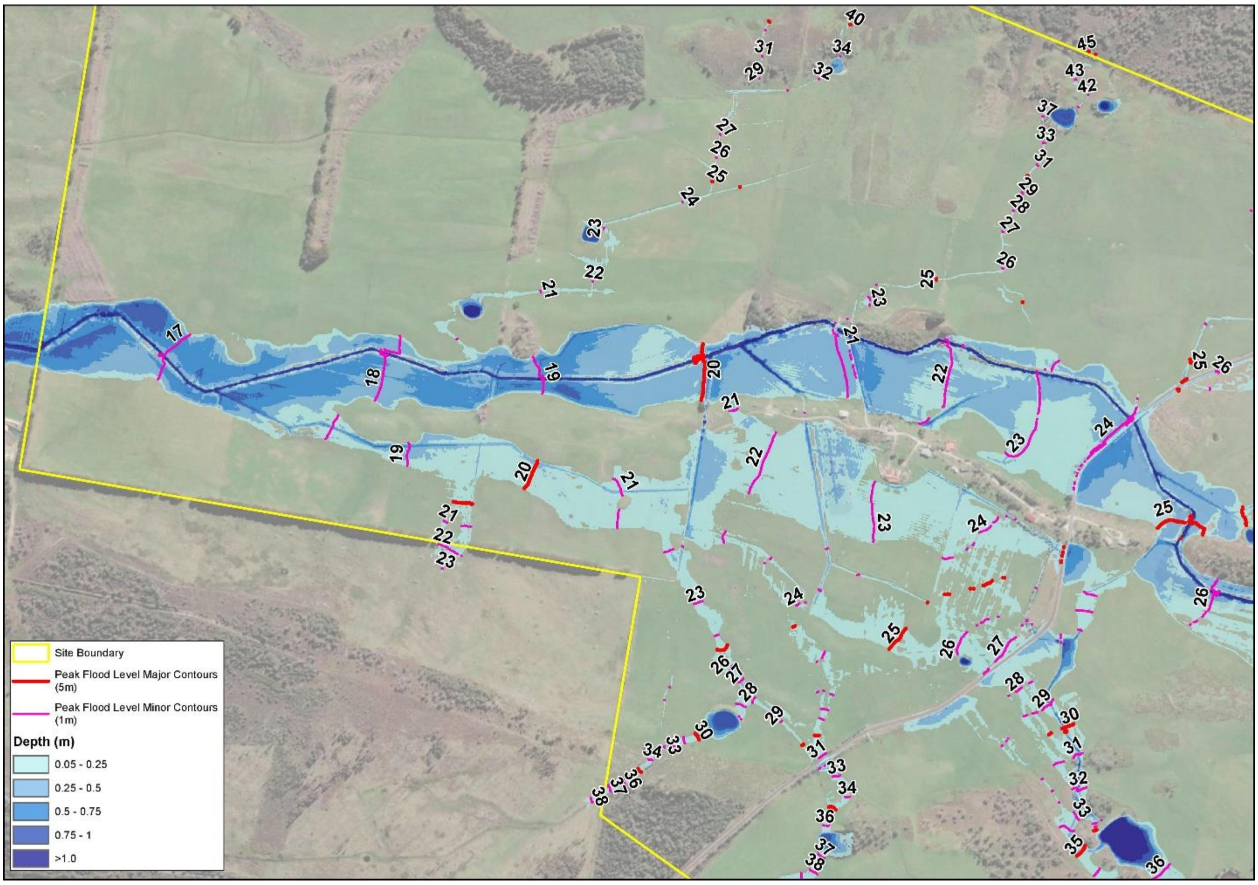

Diagram 6: Flood Inundation Downstream Part of the Site

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Figures

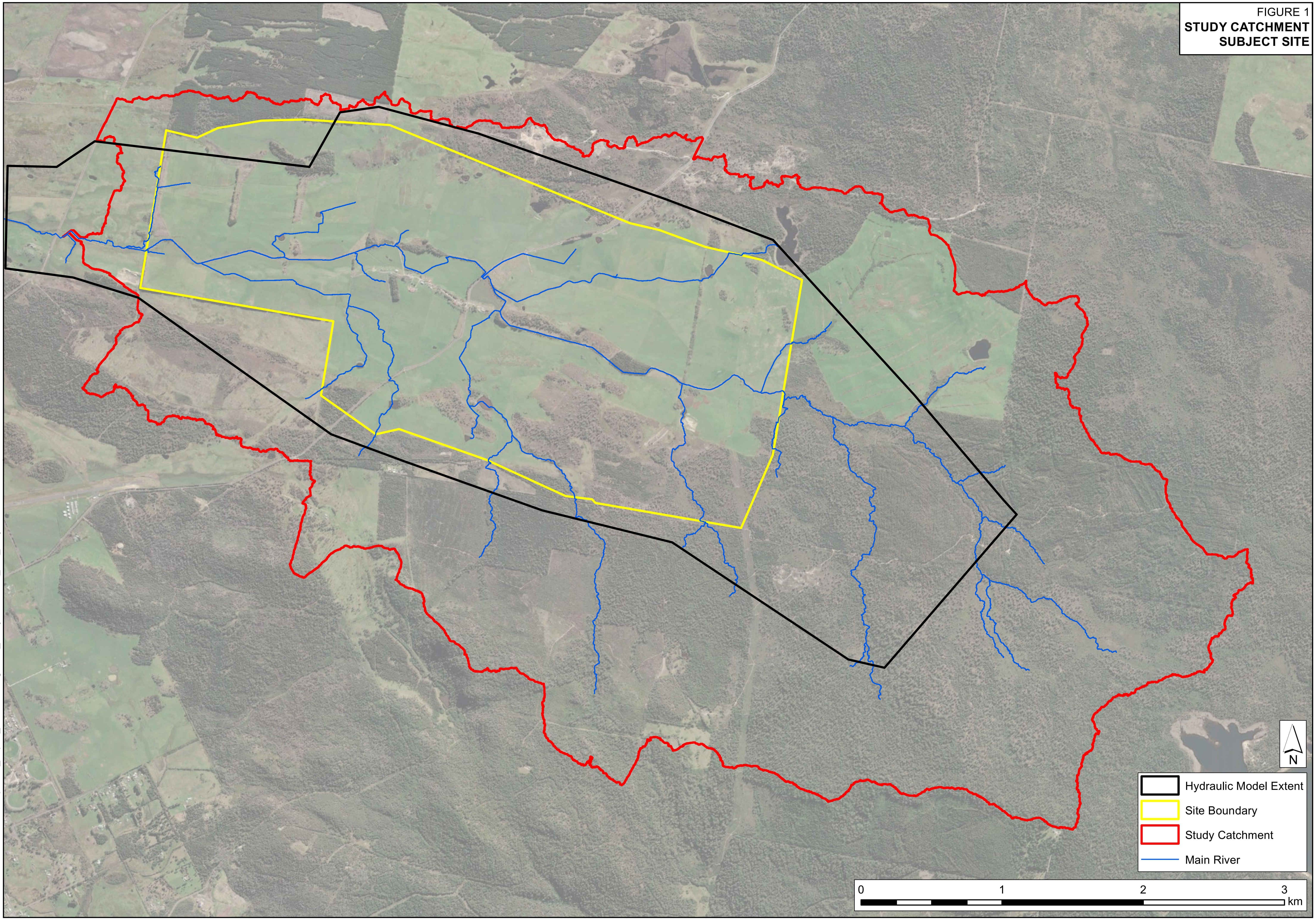
FIGURE 1
STUDY CATCHMENT
SUBJECT SITE
Hydraulic Model Extent
Site Boundary
Study Catchment
Main River
N
0
1
2
3
km
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FIGURE 2
MODEL SCHEMATICS
HYDROLOGIC SUB-CATCHMENTS AND HYDRAULIC MODEL EXTENT

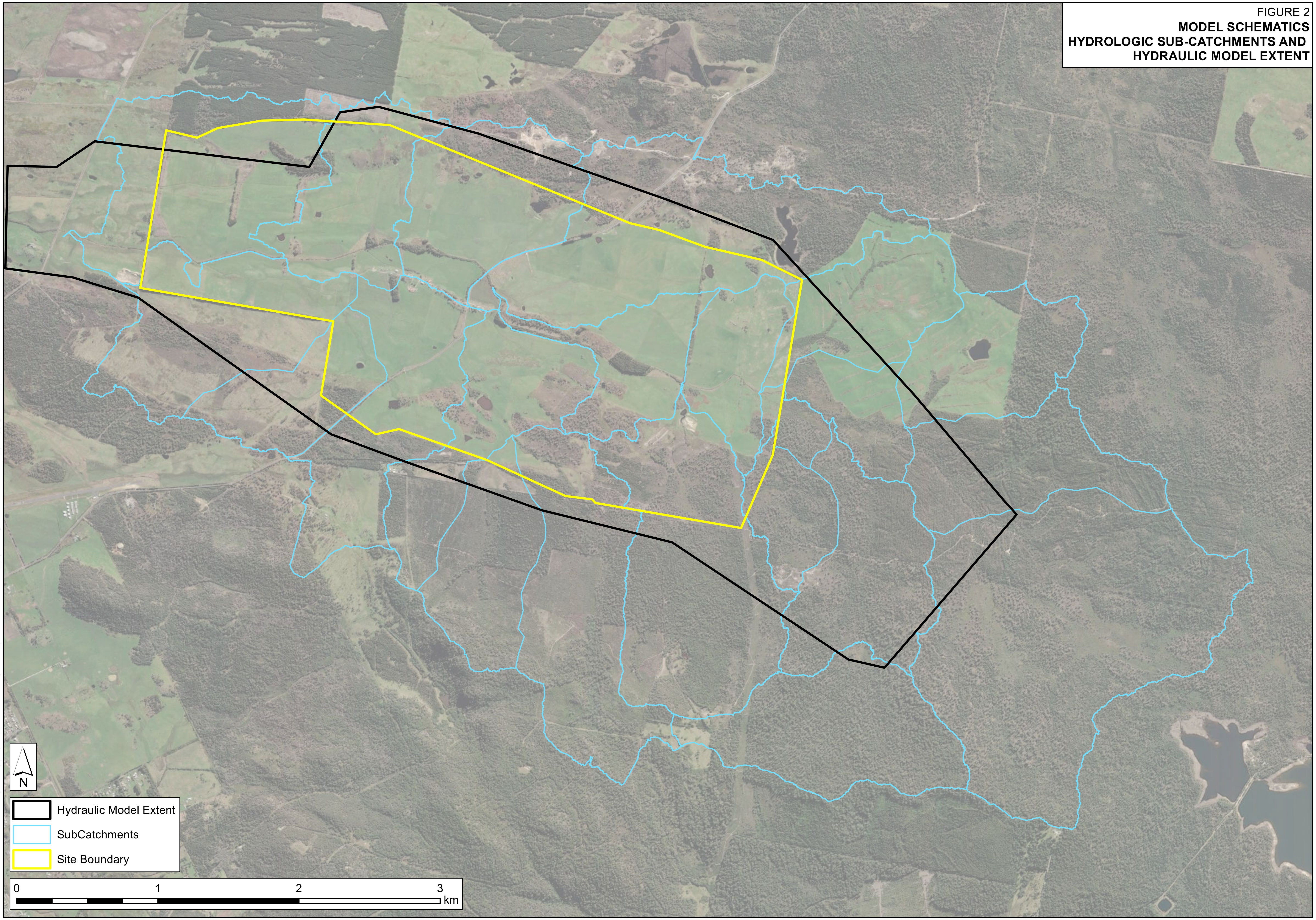

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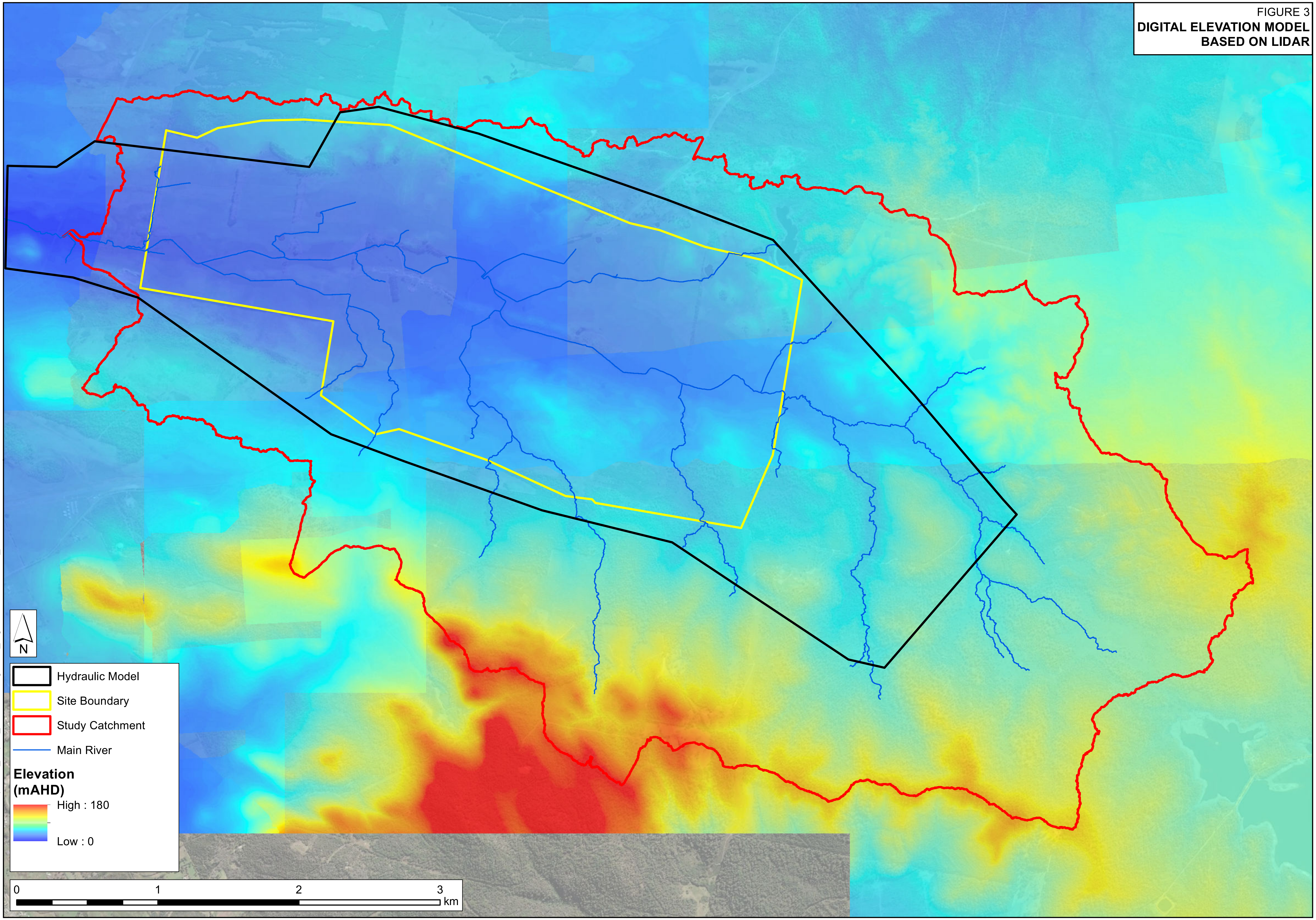
FIGURE 3
DIGITAL ELEVATION MODEL BASED ON LIDAR



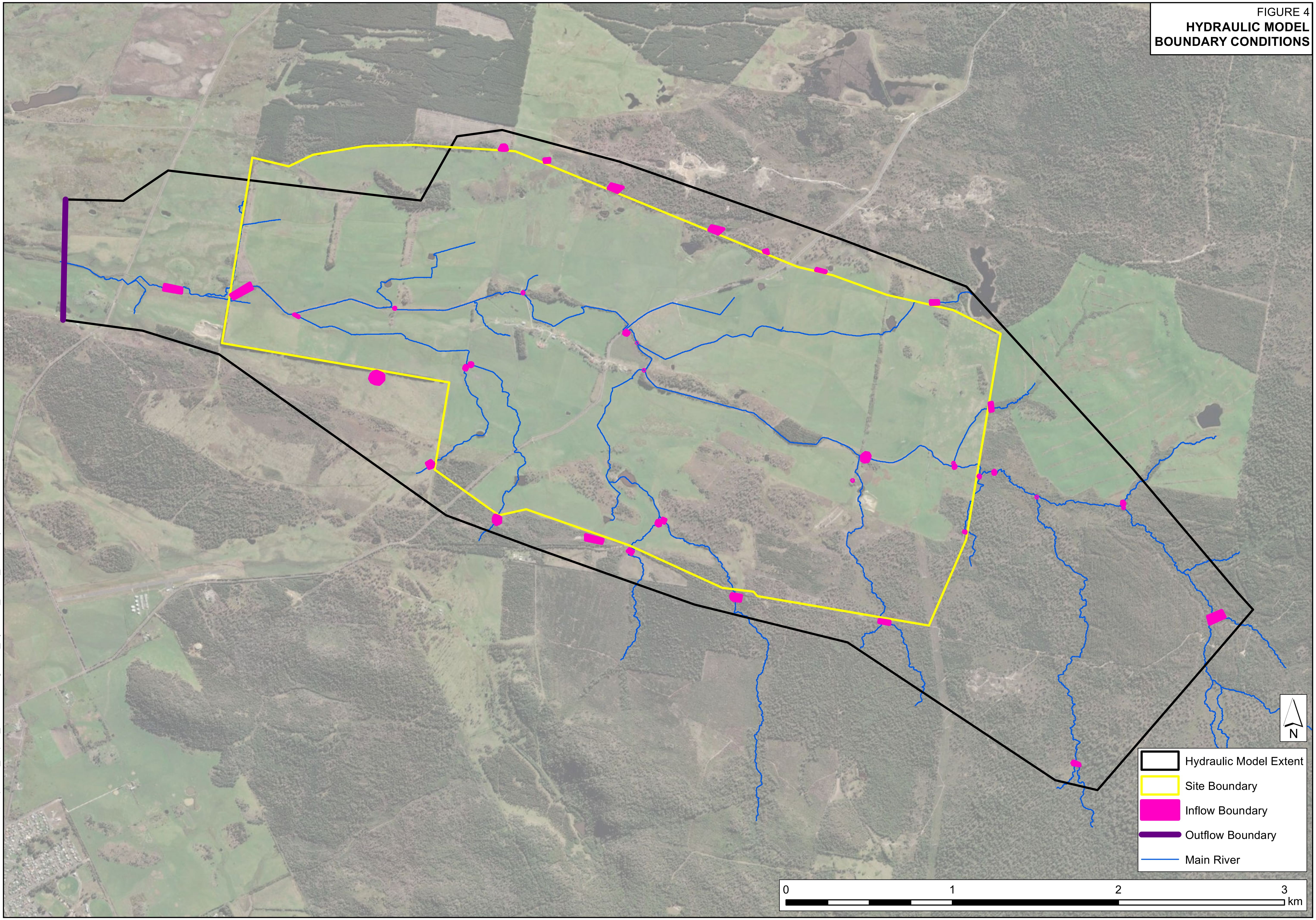


FIGURE 4
HYDRAULIC MODEL BOUNDARY CONDITIONS
Hydraulic Model Extent
Site Boundary
Inflow Boundary
Outflow Boundary
Main River
N
0
1
2
3
km
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FIGURE 5
HYDRAULIC MODEL ROUGHNESS

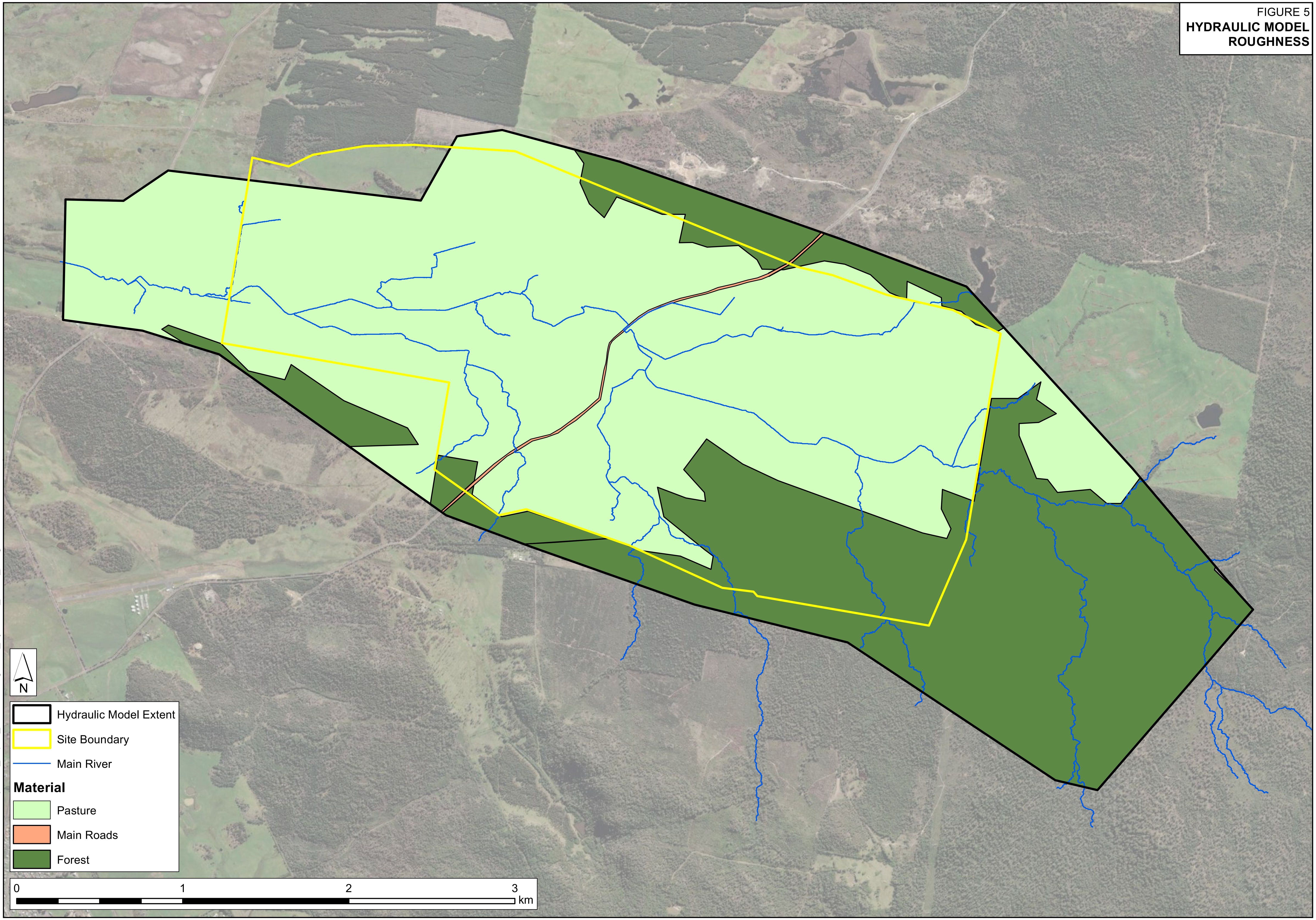

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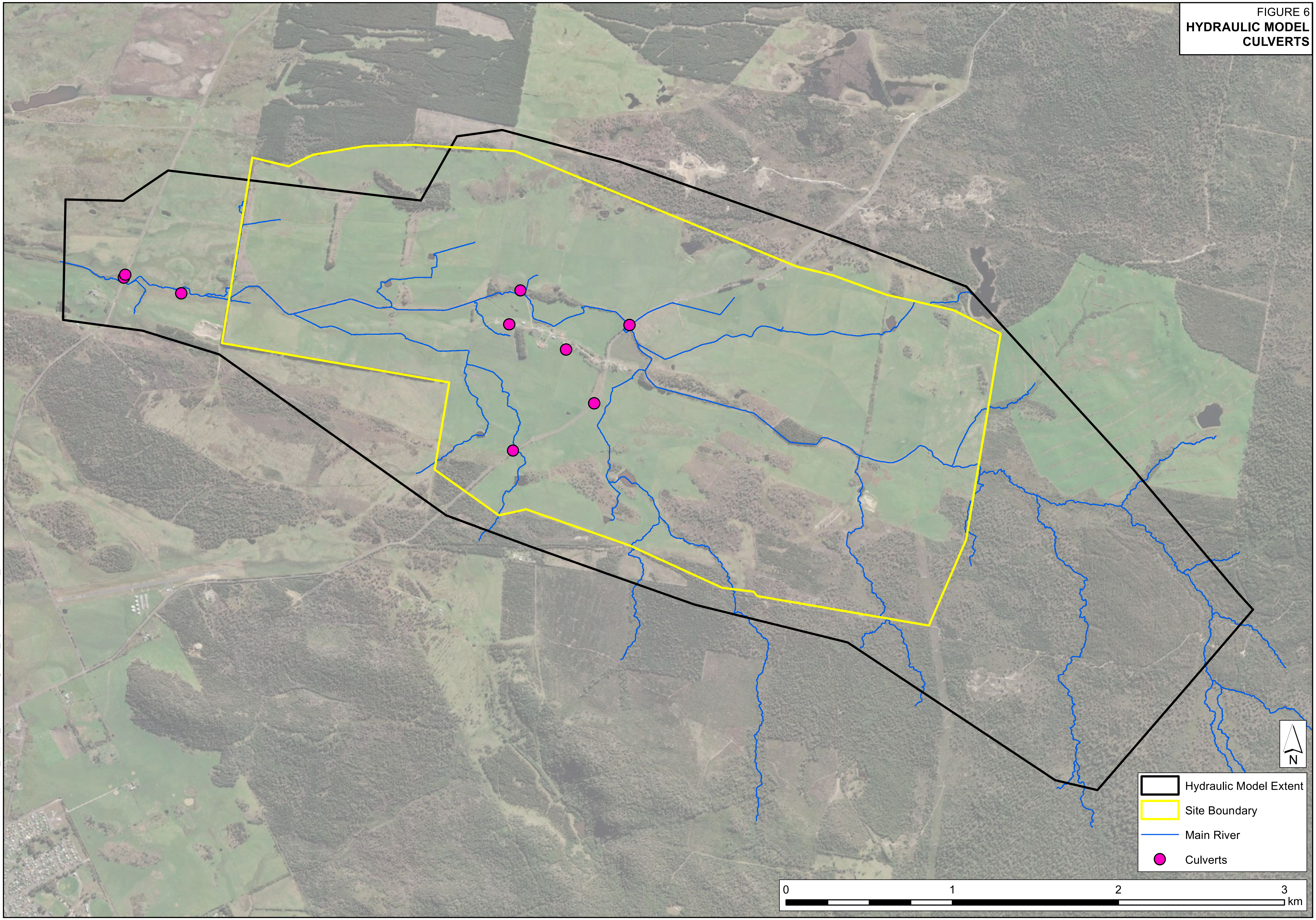
FIGURE 6
HYDRAULIC MODEL CULVERTS



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Appendix A

APPENDIX A. GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.

disaster plan (DISPLAN) A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.

discharge The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).

ecologically sustainable development (ESD) Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.

effective warning time The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.

emergency management A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.

flash flooding Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.

flood Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.

flood awareness Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.

flood education Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.

flood fringe areas The remaining area of flood prone land after floodway and flood storage areas have been defined.

flood liable land Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).

flood mitigation standard

	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the Aflood liable land@ concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL=s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the Astandard flood event@ in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood

	storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: - the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or - water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or

- major overland flow paths through developed areas outside of defined drainage reserves; and/or
- the potential to affect a number of buildings along the major flow path.

mathematical/computer models The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State=s rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

minor, moderate and major flooding Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

peak discharge The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF) The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.

Probable Maximum Precipitation (PMP) The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.

probability A statistical measure of the expected chance of flooding (see AEP).

risk Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.

runoff The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.

stage Equivalent to Awater level@. Both are measured with reference to a specified datum.

stage hydrograph A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.

survey plan A plan prepared by a registered surveyor.

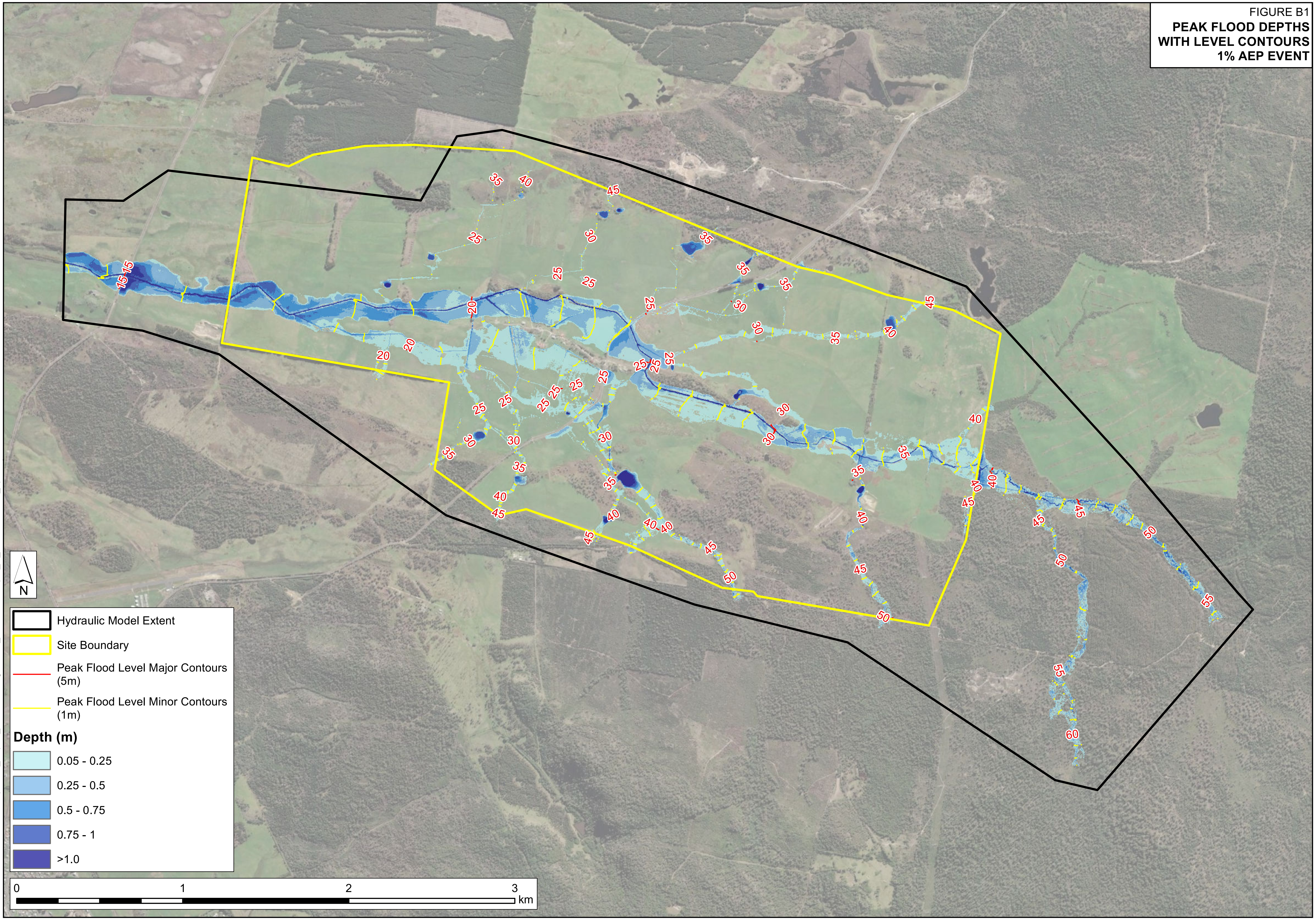
water surface profile A graph showing the flood stage at any given location along a watercourse at a particular time.

wind fetch The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

APPENDIX B. DESIGN EVENT FLOOD MAPPING

FIGURE B1
PEAK FLOOD DEPTHS WITH LEVEL CONTOURS 1% AEP EVENT



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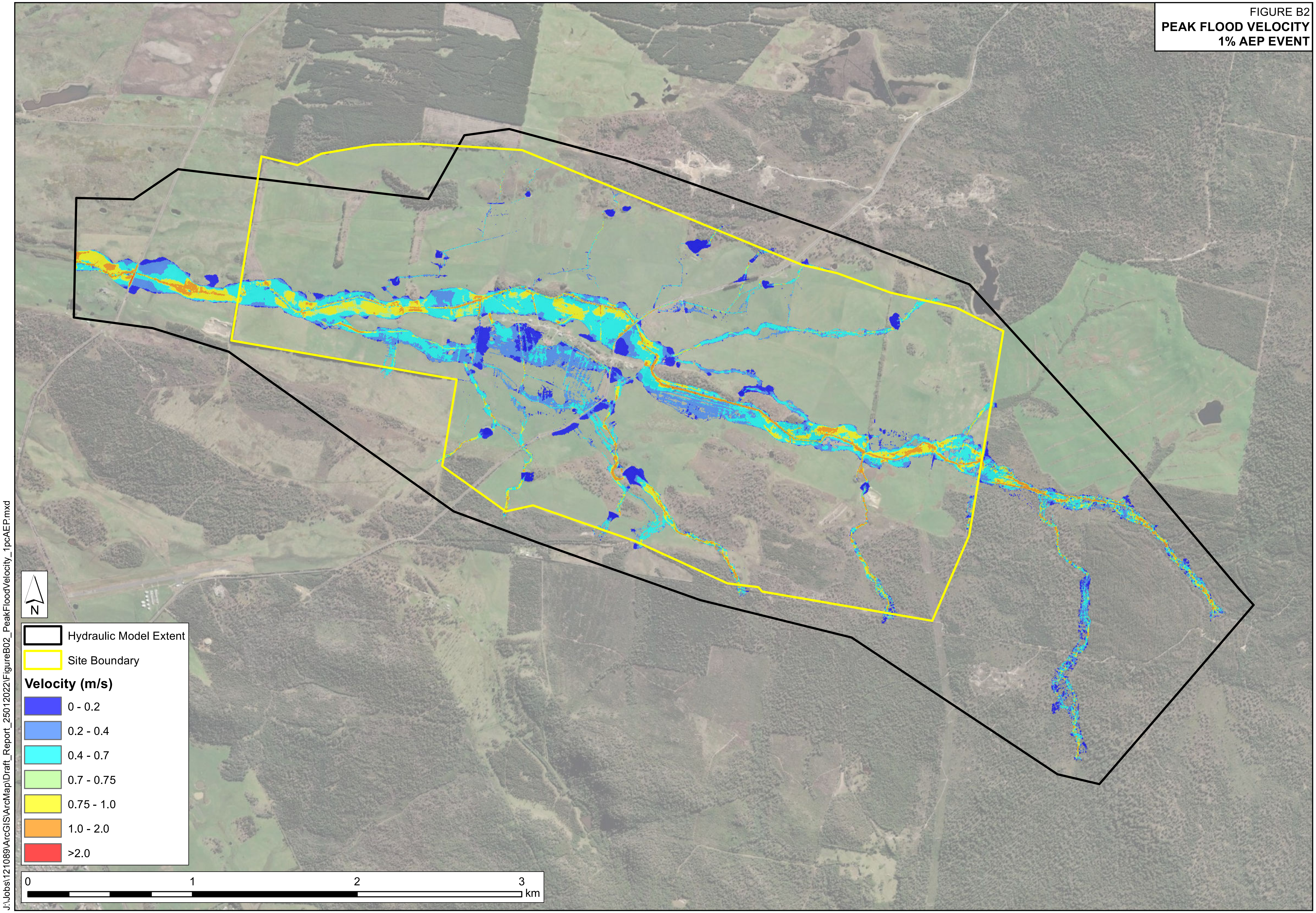

FIGURE B2
PEAK FLOOD VELOCITY
1% AEP EVENT
N
Hydraulic Model Extent
Site Boundary
Velocity (m/s)
0 - 0.2
0.2 - 0.4
0.4 - 0.7
0.7 - 0.75
0.75 - 1.0
1.0 - 2.0
>2.0
0
1
2
3
km
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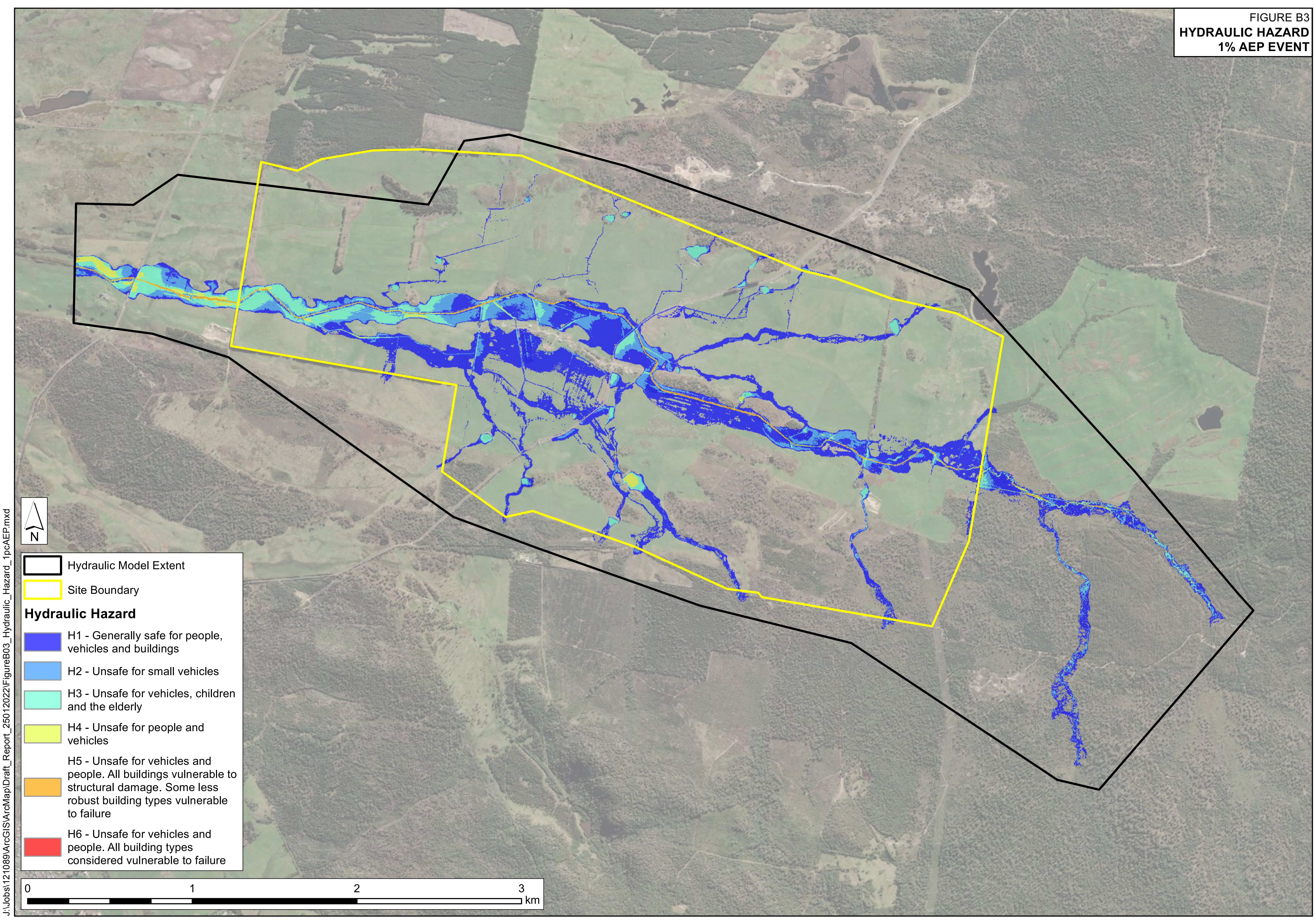

FIGURE B3
HYDRAULIC HAZARD
1% AEP EVENT
N
Hydraulic Model Extent
Site Boundary
Hydraulic Hazard
H1 - Generally safe for people, vehicles and buildings
H2 - Unsafe for small vehicles
H3 - Unsafe for vehicles, children and the elderly
H4 - Unsafe for people and vehicles
H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure
0
1
2
3
km
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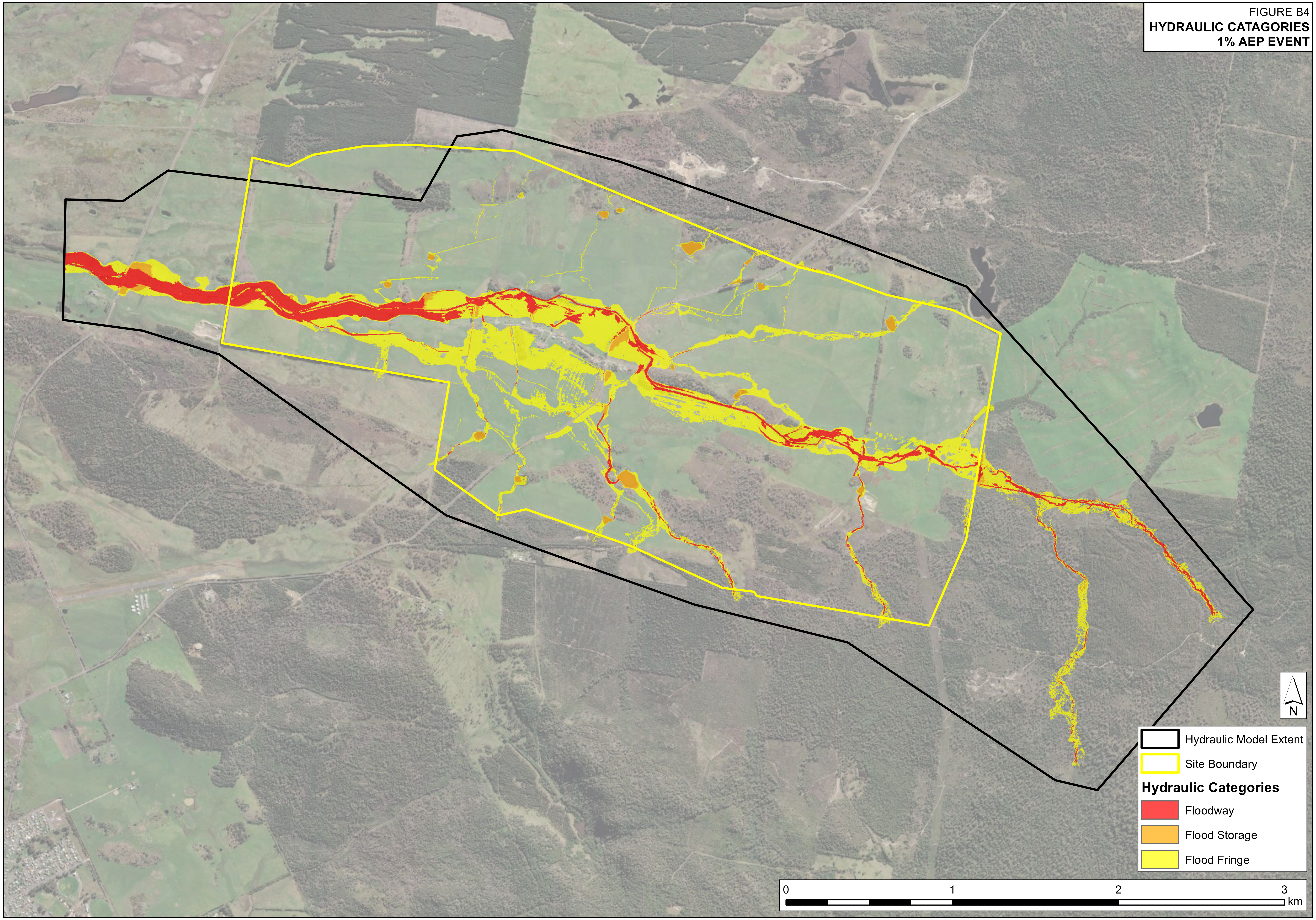
FIGURE B4
HYDRAULIC CATAGORIES
1% AEP EVENT



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